D-A Line Analysis

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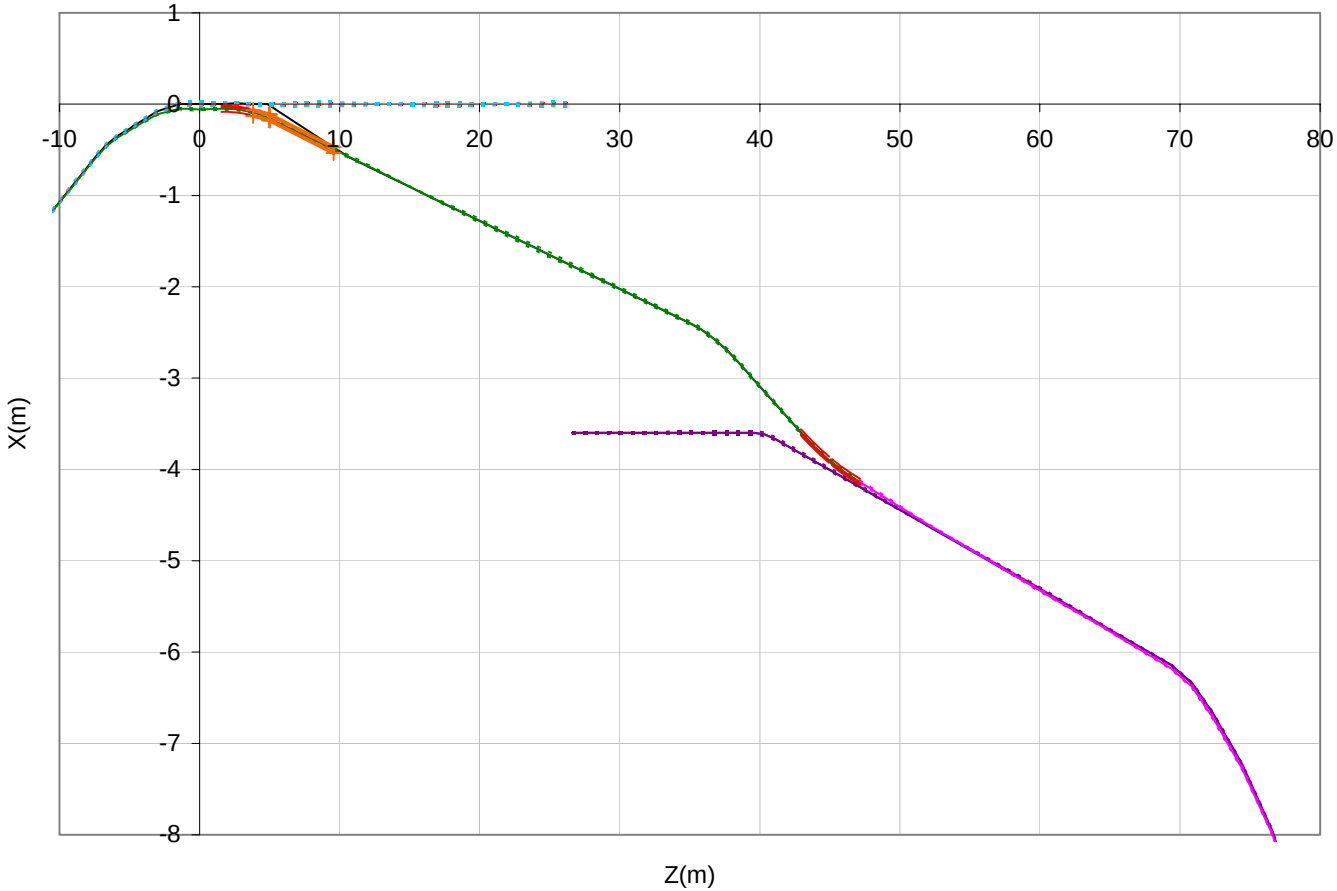
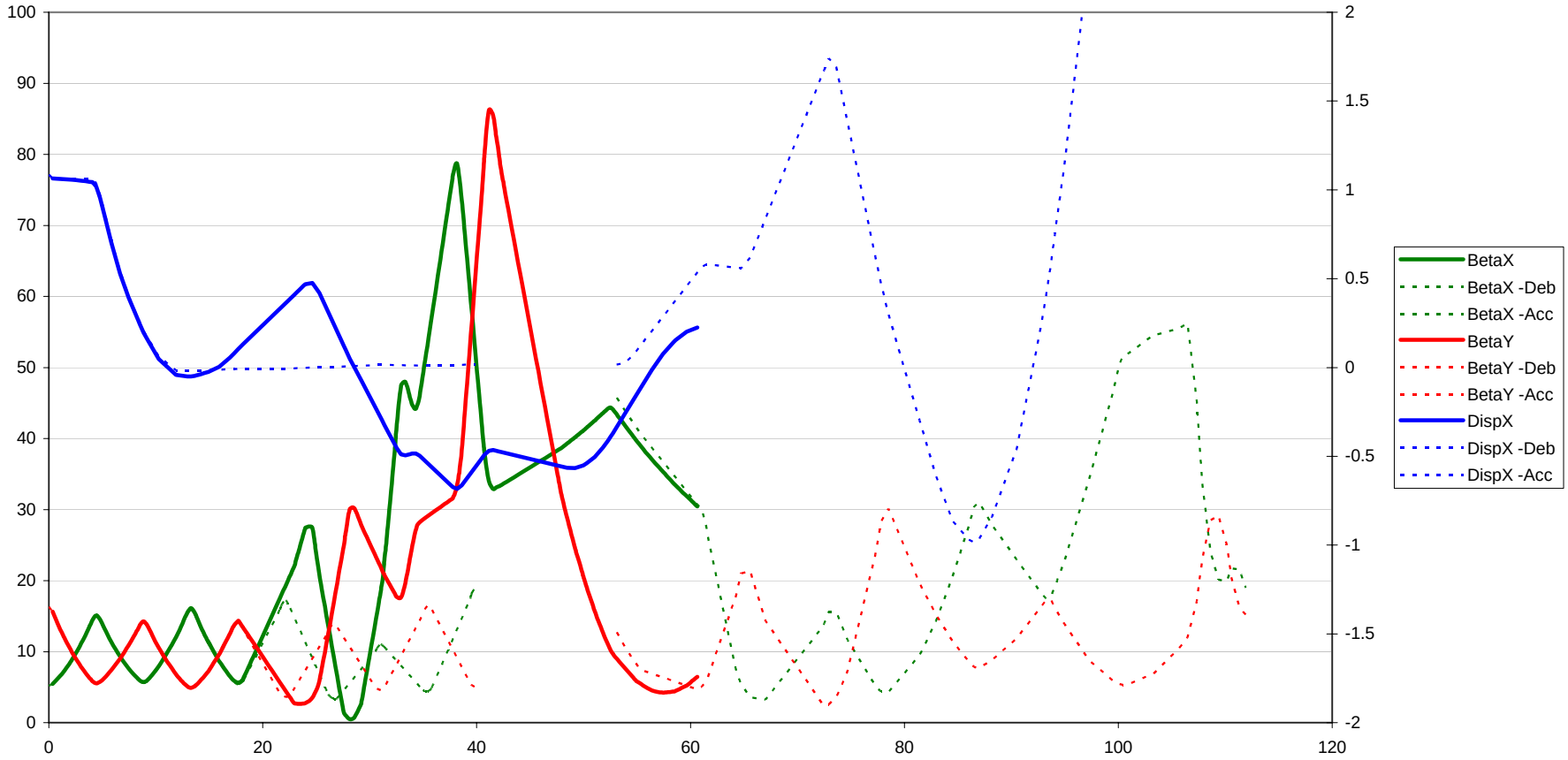
Debuncher to Accumulator Transfer Line

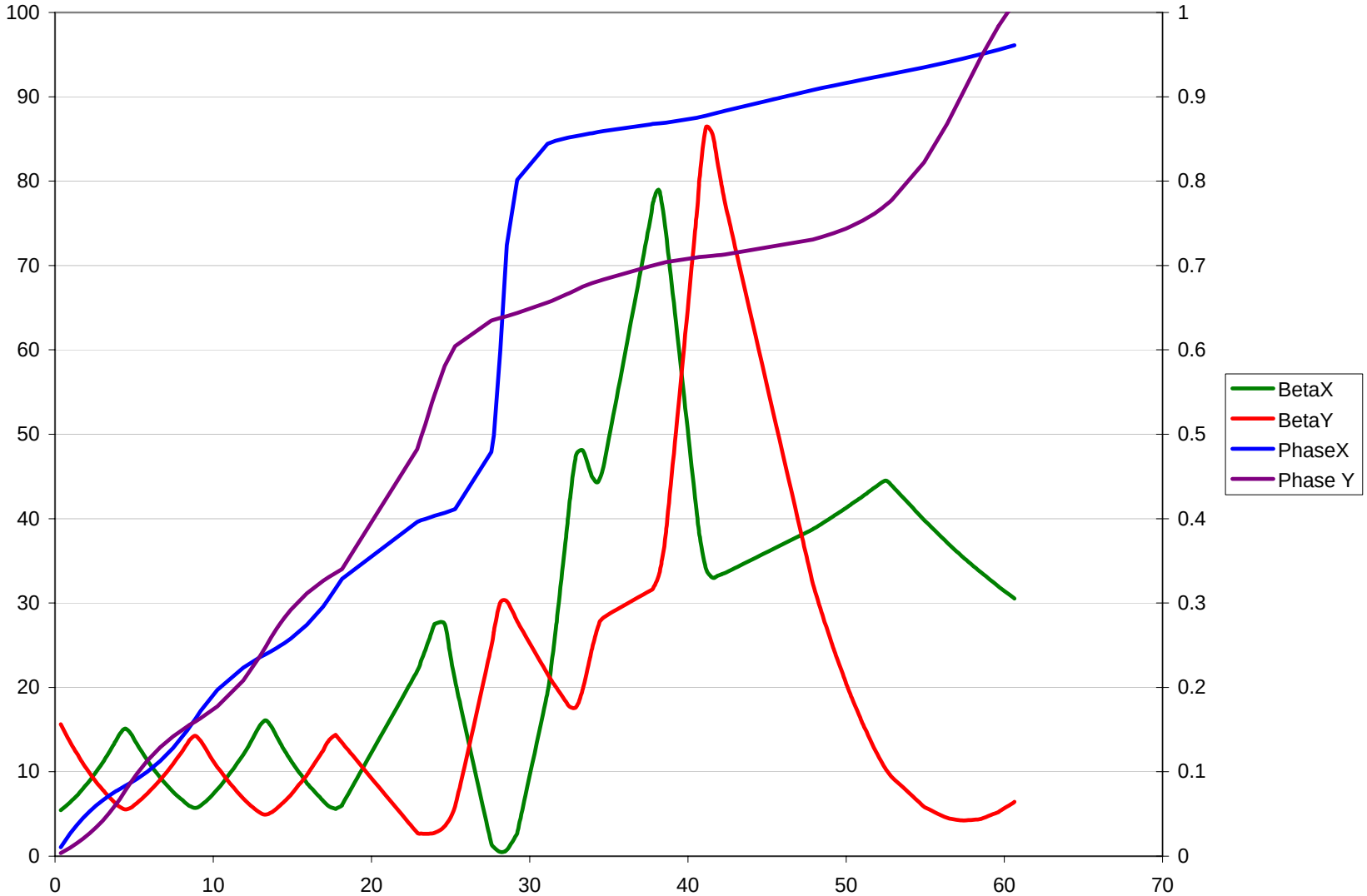


- Did a complete Laser Tracker survey of the entire D-A line from Debuncher Extraction Kicker to Accumulator A1Q5
- Built a lattice model (MAD) that matched survey coordinates to within 1-2 mm

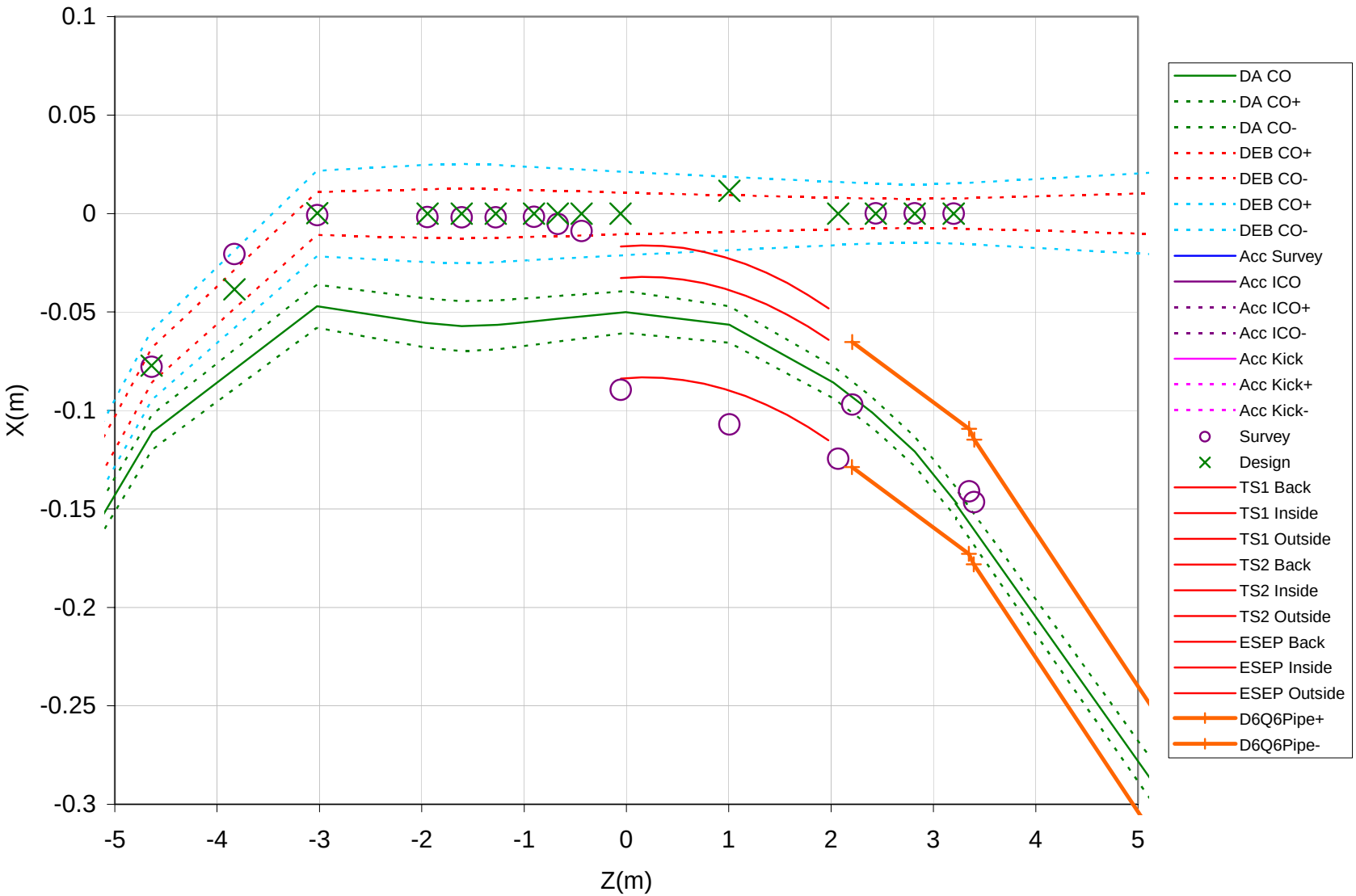
D-A Line Lattice Functions



D-A Line Beta Functions



Debuncher Extraction as Found



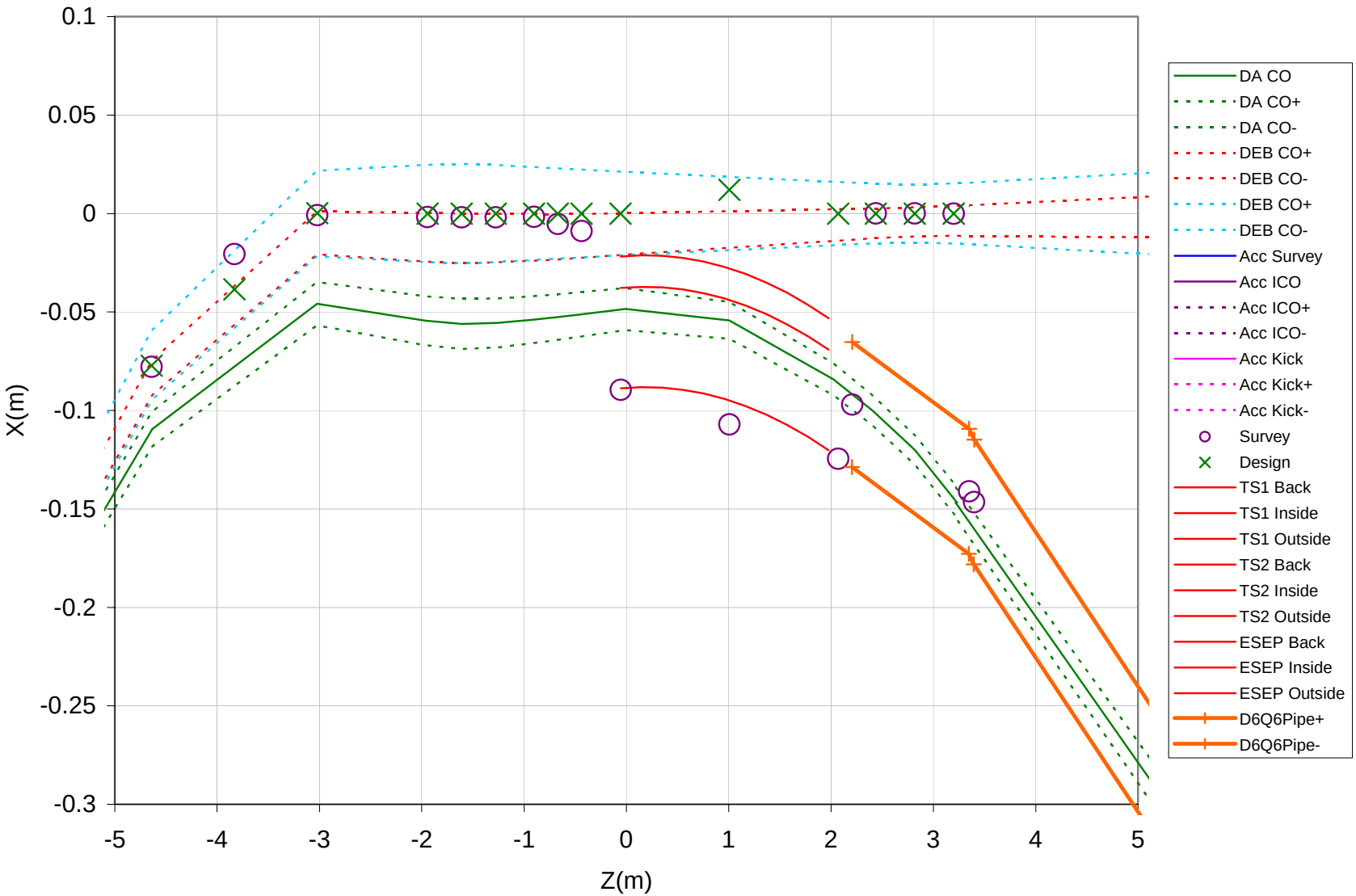
Debuncher Extraction (as found)

- Upstream end D:ESEP and "D-Pipe" need to move 5mm towards Accumulator
  - For a 40 π-mm-mrad aperture injection beam
  - For a 10 π-mm-mrad aperture extraction beam
  - A 48.4 mm separation between kicked beam and closed orbit at the Debuncher Extraction Septum
    - Need to confirm that D:EKIK can deliver at least 50mm of separation between circulating and extracted beam at D:ESEP
      - Debuncher needs 5.0 mrad kick for 48.4 mm
      - Accumulator needs 2.6 mrad for 50 mm.
      - Both kickers are running close to max voltage of 60 kV
- Installing DEX Bump (Ramped 3 bump at the Debuncher extraction septum) to compensate insufficient kicker voltage
  - Bump is off when injecting beam to maximize injection aperture
  - Bump is on when extracting beam to snug up closed orbit to the septum as close as possible for a 10 π-mm-mrad
  - Next injection immediately follows extraction so bump must ramp down fast.

Debuncher Extraction Bump

- Bump is composed of:
  - NDA trim just upstream of the Debuncher bend B608
  - NDB trim at H606
  - NDA trim just upstream of Q605
  - Ratio = 1: -1.151 : 0.886
- A Dex Bump with an amplitude of -12 mm at H606 will bring the inside edge of a 10 π-mm-mrad circulating beam for extraction to the inside edge of an injected 40 π-mm-mrad beam
- The kicker angle needed is now 3.87 mrad (reduction of 23%)
  - Requires a bend ratio of 1.2 : -1.38 : 1.06 mrad
  - Requires a current ratio of 19.9 : -19.45 : 17.57 A
- Power Supply Voltage
  - The inductance of an NDA is ~450mH and the resistance is ~750mΩ
  - An inductive voltage of 100V could ramp the 12 mm bump in 90mSec
    - Shortening the Debuncher cooling cycle time by 90mSec for a 2 second cycle time would increase the tranverse emittance by 7% for a 1.3 sec cooling time constant
    - If there is no DEX bump and the kicker voltage is 3.87 mrad.,
      - The center of the extracted beam will hit the septum edge
      - Therefore only 50% of the beam will make it through the Debuncher extraction septum.
  - The resistive voltage swing is 15V

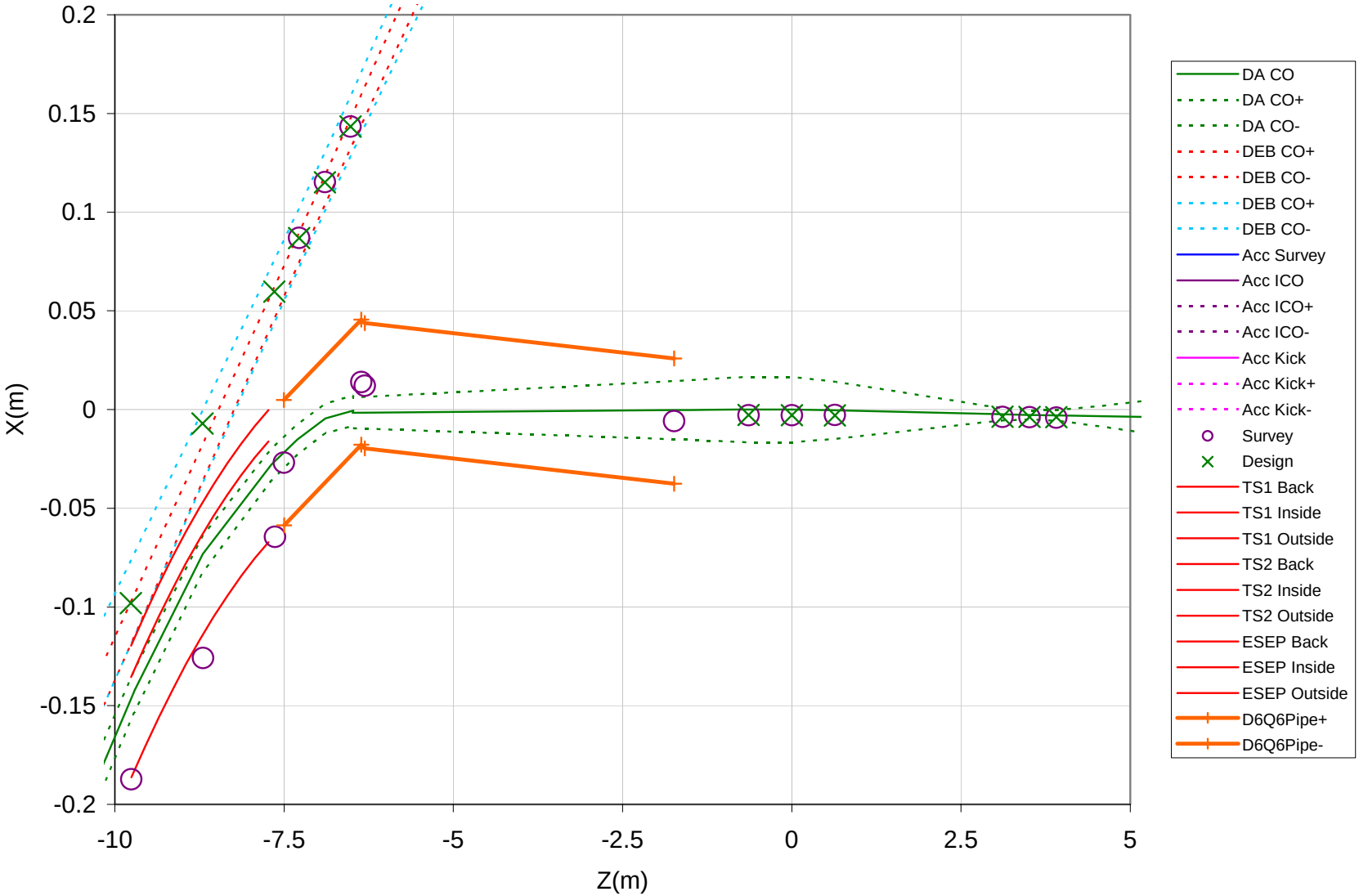
Debuncher Extraction with DEX Bump and Septum Move



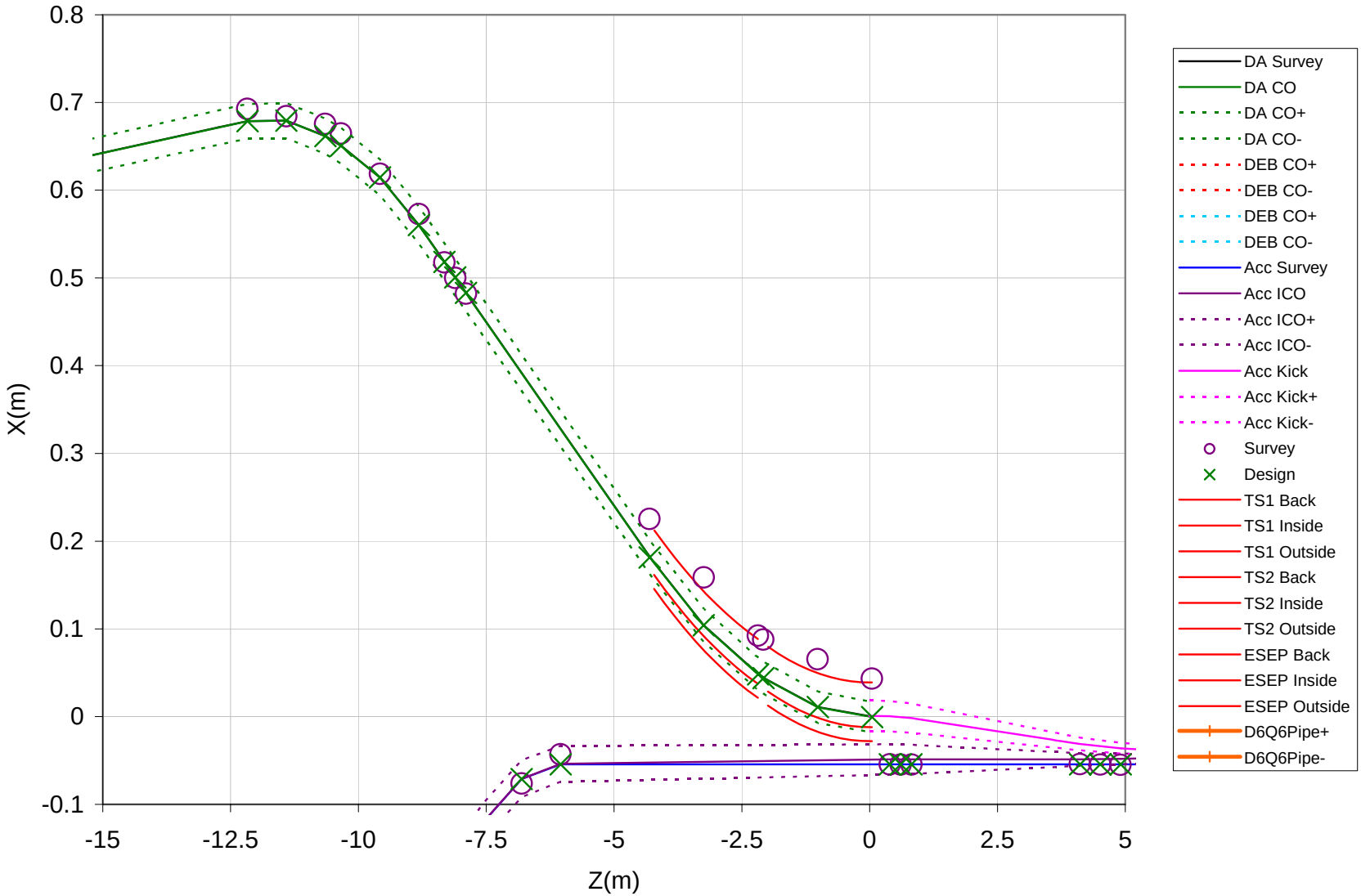
Injecting into the Transfer Line

- Injection into the transfer line must satisfy 3 constraints:
  - Beam Separation at the extraction septum
    - Set by the extraction Kicker voltage
  - Angle of the transfer line with respect to the Debuncher
    - Set by the location of the quads in the transfer line
  - Intercept of the transfer line with respect to the Debuncher
    - Set by the bend by going off-center through the Debuncher quad D6Q6
- There are only 2 knobs to control injection into the transfer line
  - Extraction kicker voltage
  - Extraction Septum bend angle
    - The gradient on D6Q6 is adjusted for Debuncher lattice properties
- According to the lattice model and magnetic field measurements of D6Q6 there is a 2-3 mrad error in the bend needed by D6Q6 to center beam in TQ1
  - An alternative is to correct the distortion at TQ3 by using a 0.7mrad kick at D:HT804.
  - The angle introduced by DEX bump would reduce the required kick to 0.4mrad at D:HT804
  - This requires beam based alignment techniques
    - Adjust Debuncher extraction septum bend so that beam is centered in TQ3
    - Adjust D:HT804 so that beam is centered in TQ6
    - Requires measuring trajectory perturbations WITH PBARS!!!
      - Installed a forward PBAR BPM system in the line
      - Built a forward PBAR TBT system in the accumulator
      - Developed a technique for bunching the forward PBAR beam
- A 2.5" diameter beam pipe at D6Q6 is close to being an aperture restriction for a 10 π-mm-mrad beam.
- Quads and trims in the transfer line are within 1-2 mm of alignment
  - TB1&2 out of alignment horizontally, but aperture is still acceptable

Injecting into the Transfer Line



Accumulator Injection (as found)



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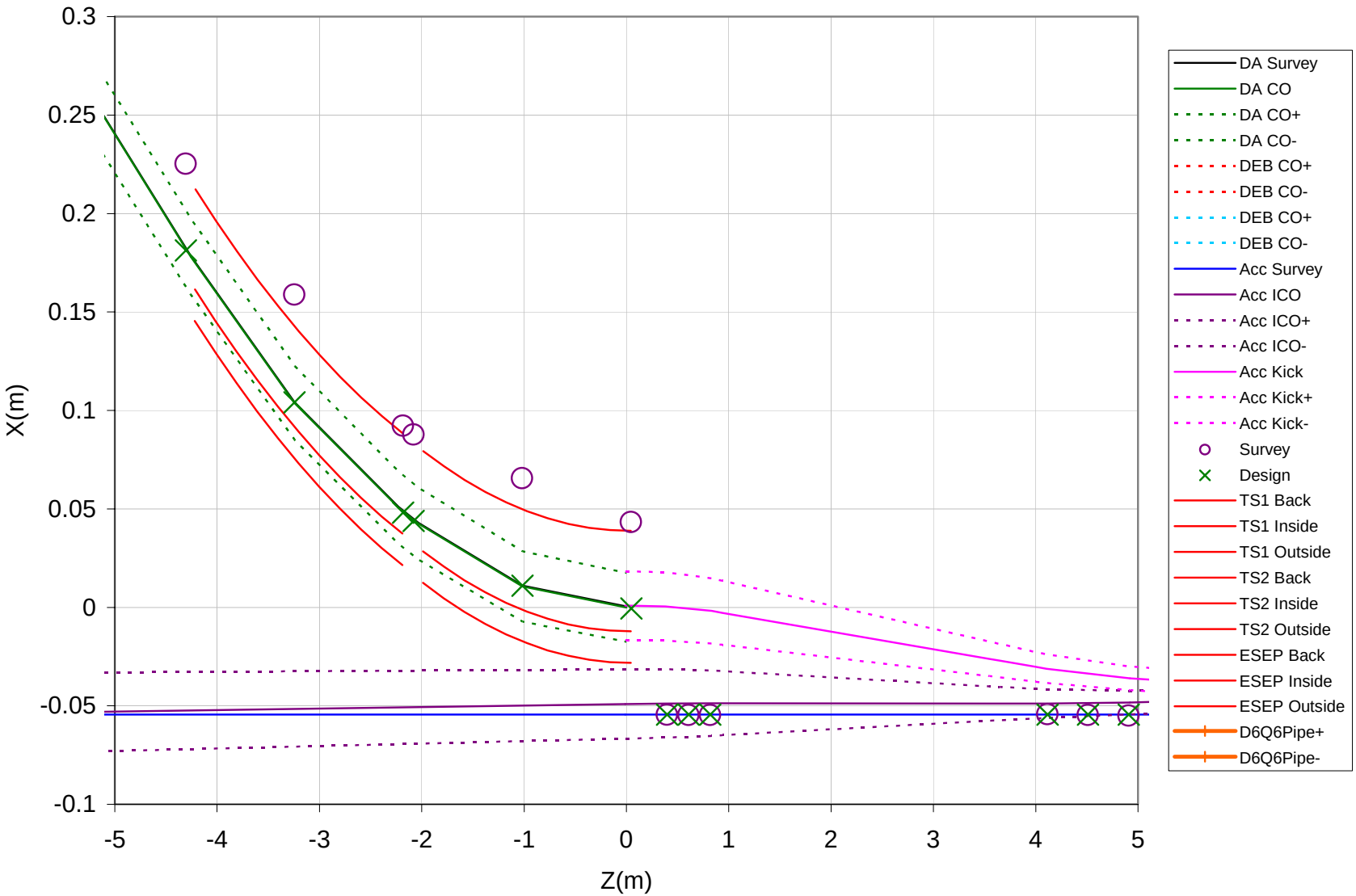
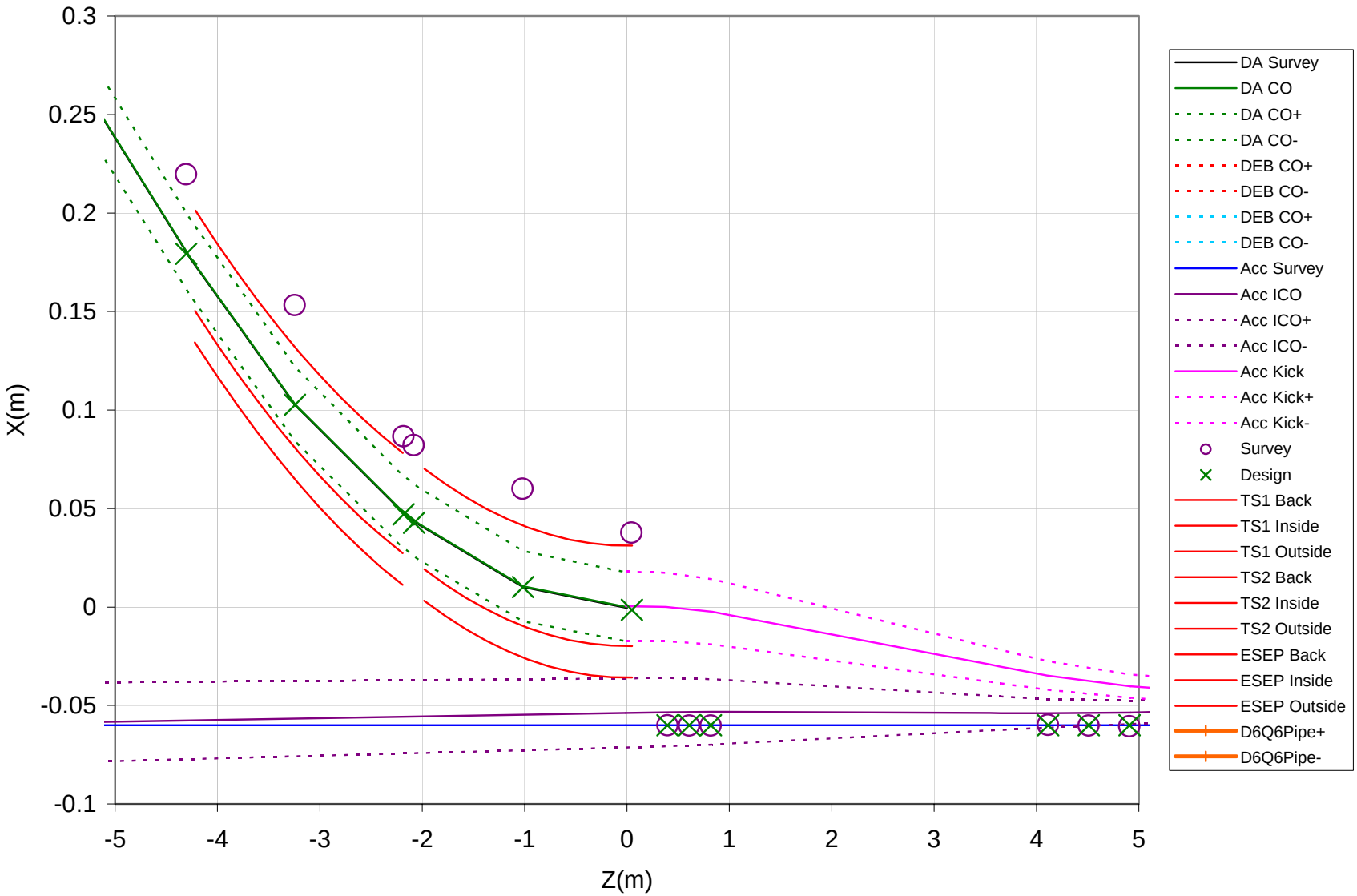


Accumulator Injection

- A:ISEP1 was shunting current into the beam pipe and has been replaced
- The upstream ends of the Accumulator Injection Septa need to move closer to Accumulator by about 5mm
- Downstream end of A:ISEP1 constrained by Accumulator "D-pipe" and shouldn't be moved
  - For 50 mm kick amplitude at A:ISEP1
    - 10 π-mm-mrad beam clips by 4.5mm at downstream end
    - 5 π-mm-mrad beam just fits
  - Increasing Kicker Amplitude by 12% will clear 10 π-mm-mrad beam
    - Need a 2.6 mrad kick for 50mm
      - Debuncher needs 5.2 mrad kick for 50mm
    - Current running at 58kV out of a possible 65 kV
  - 10 π-mm-mrad circulating beam has 3.5 mm of elbow room
    - Install a three bump at Accumulator Injection
      - BS103,Q104,H105 (2.53 : 2.89 : 1)
        - » 3.5 mm at Q104 would require 2.62 Amps on H105
        - » The 3 bump would reduce the required kicker voltage increase to 5%
      - Do not have a trim at Q104 (6" beam pipe)
        - » Modified and installed a 5.5" aperture NDB trim to have a 6.5" aperture

Accumulator Injection with Septa Move, Q104 bump, and Kicker Increase



D-A Line Initial Beam Studies

- Check-out instrumentation
  - Forward pbar and reverse proton timing for transfer line SEMs
  - Ring SEMs A104 and D607
  - Beam bunching procedures
    - Forward pbar extraction from the Debuncher using adiabatics.
    - Reverse proton extraction from the Accumulator using ARF1
  - TBT Systems
    - Forward pbar system in the Accumulator
    - Reverse proton system in the Debuncher
  - Forward pbar BPM system in the transfer line
- Debuncher Extraction and Accumulator Injection Beam separation versus kicker voltage using ring SEMs
- Transfer line transfer function matrix
  - Measure differential orbits of one-bumps with transfer line BPMs
    - Easy to do but coverage is limited by the number of BPMs
  - Measure effect of varying Quad currents on a one bump excitation with TBT system
    - Hard to do but transfer function of every quad can be measured.

D-A Line Tune-up Philosophy

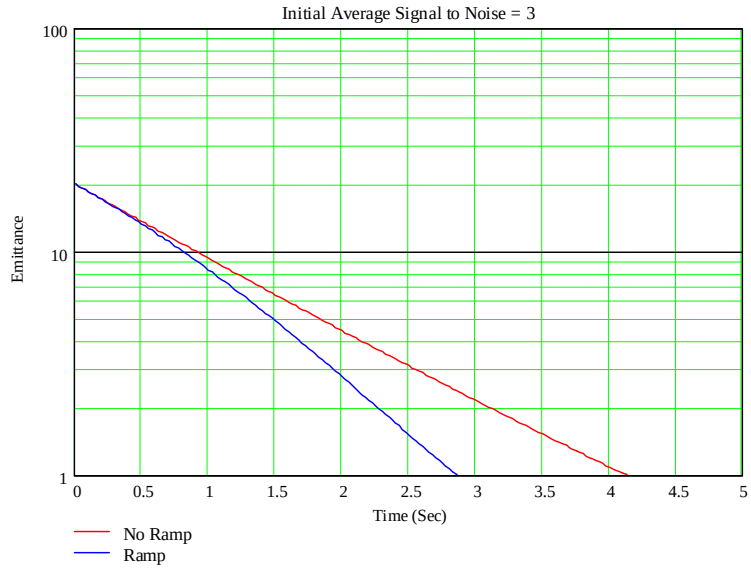
- Because TQ1 -TQ6 are surveyed very close to an ideal line, the trajectories through the Debuncher and Accumulator septa can be established independent of each other as long as each trajectory goes through the centers of TQ3-TQ5
- The goal for the Debuncher is to scan the kicker voltage (D:EKIK) to find the minimum kicker voltage needed to pass 100% of a pbar beam that has been cooled for 2 seconds
- The goal for the Accumulator is to scan the kicker voltage (A:IKIK) to find the minimum kicker voltage needed to pass 100% of a reverse proton beam that has been heated to the aperture limit of the Accumulator injection orbit

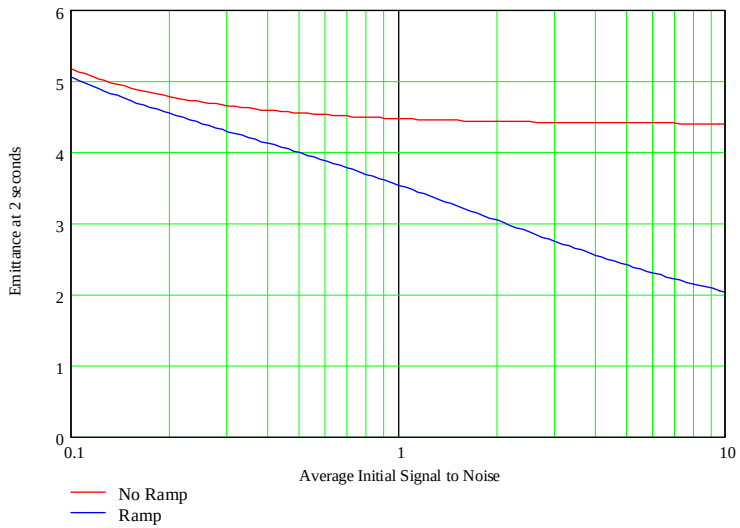
D-A Line Tune-up Procedure

- Reverse Proton- Accumulator Injection tune-up
  - Use new injection three bump to snug beam against Accumulator Injection Septa but not limit the injection orbit aperture with this bump.
  - Develop position and angle bump for reverse protons forTQ6 through TQ4 using D:H807 and Accumulator Injection Septa current
  - Scan Accumulator Injection kicker voltage:
    - Adjust Accumulator Injection Septa to center beam on TQ7 using BBA instrumentation
    - Adjust position and angle bump to center on TQ6-TQ1 using BBA instrumentation
    - Heat beam in Accumulator to aperture and measure intensity of beam on 807 SEM or TQ7 BPM intensity signal
- Forward Pbars - Debuncher Extraction Tune up
  - Adjust DEX Bump
    - Maximum aperture at injection
    - For the minimum cooling cycle time, snug beam against extraction septum at the end of the cooling cycle.
      - Measure beam intensity in Debuncher at the end of the cycle with momentum cooling schottky signal.
  - Scan Debuncher Extraction kicker voltage:
    - Adjust Debuncher Extraction Septum current to center on TQ3 using BBA instrumentation.
    - Adjust D:HT804 to center on TQ5 and TQ6 using BBA instrumentation
    - For the minimum cooling cycle time, measure the intensity of beam on D-A Line SEMS or BPM intensity signal
  - Compensate for directionality of the Accumulator Injection Kicker
    - Adjust Accumulator Injection kicker voltage to close orbit using Pbar TBT

Gain Ramping the Debuncher Transverse Stochastic Cooling Systems

- Debuncher Transverse Stochastic Cooling systems:
  - Have reasonable signal to noise
  - Are power limited (don't have enough TWT power)
- As the beam cools in the Debuncher, TWT power shrinks as well.
- If the cooling system gain is ramped up to keep TWT power constant, than the emittance can be further reduced.





Improvements to the DA Line

- Laser Tracker survey of the D-A Line
- Developed Lattice Model for survey predictions
- Realignment of the septa
  - Debuncher extraction
  - Accumulator Injection
- Installation of the DEX bump
- Replacement of A:ISEP1
- Developed beam based procedure for aligning beam in transfer line
  - New BPMs and new TBT system
  - New bunching procedure
- Installation of an Accumulator injection 3 bump
- Installation and analysis of Debuncher Gain ramping